Trapping transients: line surge protection

Data communications lines and equipment are vulnerable to electrical transients. Assessment of the application guides proper surge protection.

By Alex Gorosito

Today's data equipment is vulnerable to voltage surges and electrical transients. A single IC package can contain more than 100,000 memory bits and more than 5,000 logic gates. The high sensitivity, due to the small size of the chips used in these packages, makes them susceptible to quick degradation from voltage surges and transients. PLCs, MUXs, HUBs, RTUs, SCADA, and telemetry equipment are especially vulnerable to electrical surges because of their low operation voltages. Many of these components can be damaged beyond repair by an electrical surge as low as 20V.

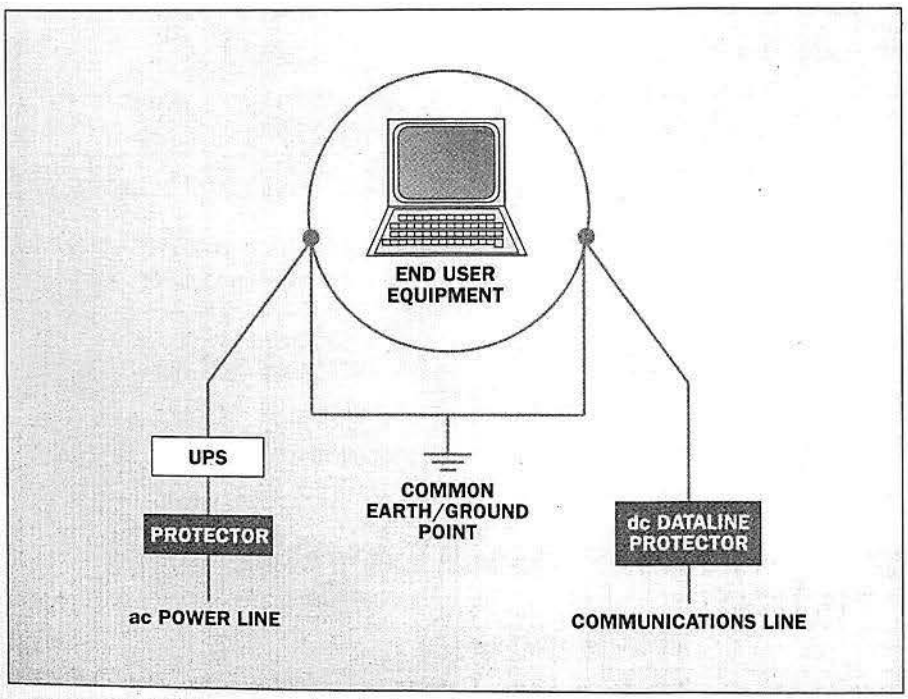

Figure 1. A lightning surge or transient can invade equipment via various routes.

Sources of electrical surges are numerous. The most common is a close lightning strike, which will affect nearby data lines through induction. Industrial transients caused by switching and commuting of electrical motors are also significant disturbances. The operation of such devices can cause abrupt shifts in the ground potential that can generate a current flow through a nearby dataline to equalize the ground potential.

Electrostatic discharge (ESD) is another form of an electrical surge that can be included in this group. Although often overlooked, ESD can harm fragile data equipment. ESD is caused by two non-conducting materials rubbing together, causing electrons to transfer from one material to the other. Once the material comes in contact with another object of lower electrical potential, a discharge occurs. Lightning strikes are

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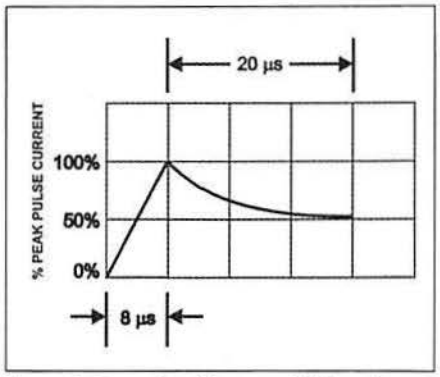


Figure 2. Power-handling capabilities of most surge protectors are commonly tested against a hypothetical surge in an 8/20µs waveform.

the most severe cases of ESD.

The consequences of electrical surges and transients may be severe. Although the event is brief, the amount of energy that is carried can be great. A typical transient event can last from a few nanoseconds to several milliseconds, carrying several thousand volts and at least a few hundred amperes of current. These events may cause burnt line cards, lockups, loss of memory, problems in retrieving data, altered data, and garbling. The user who first thinks of damage in terms of hardware problems or an ac power-related problem often overlooks all these unfavorable effects.

Transient suppressors

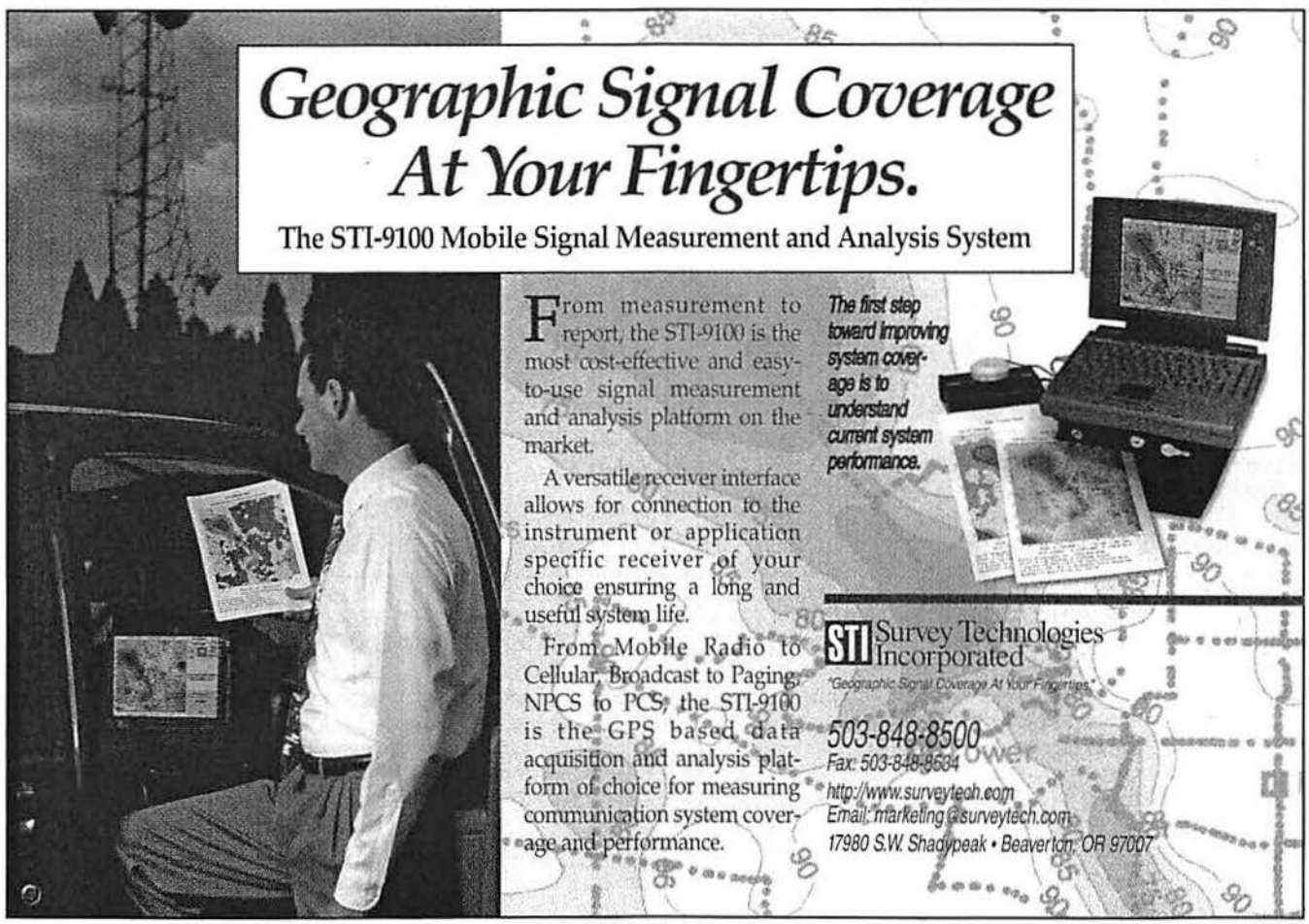
Any piece of equipment can be considered as having a protective halo around it that can be invaded in two ways: through the power line or through the communication line (i.e., telephone line, coaxial line, RS-232, RS-422, R-485, RS-423, and 4-20mA current loop cables).

Figure 1 on page 26 illustrates how equipment, such as a dispatch computer, should be protected. Both the ac power line and the dc communication line provide direct paths through which voltage surges and electrical transients can travel and damage the equipment. A common mistake is to believe that a surge protector is not necessary on the ac power line because the uninterruptible power supply (UPS) provides adequate surge protection. The main function of the UPS is to provide continuous power for a limited amount of time during a brownout or power outage. Although the UPS may provide some protection, its power-handling capabilities and response times are mediocre at best.

It is also vital that all surge protectors and UPSs be grounded to a common earth/ground as shown in Figure 1. This avoids differences in ground potentials that may generate a current flow through a nearby dataline to equalize the ground potential.

To protect equipment from incoming surges through the dataline, the user must first determine the electrical specifications of the equipment being protected. Generally, dc communications applications can be broken down into two line-type categories: twisted-pair wires and coaxial cable.

Twisted-pair applications are the most common form of wiring in data communications. They consist of two identical wires wrapped together in a double helix. Both wires in the pair have the same impedance to ground, making the pair a balanced medium. This characteristic helps to lower the wiring's susceptibility to noise from neighboring cables or external sources. A common example of a twisted-pair application is a telephone line. A single telephone line consists of two copper wires: one for transmitting electrical impulses and one to receive them. Coaxial applications, on the other hand, consist of a solid wire core surrounded by one or more foil or braided-wire shields, each separated from the other by a plastic insulator. The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inner core carries the signal, and the shield provides the ground.

Protecting twisted pairs

Once the type of application is determined, the proper type of surge protector must be selected. Whether it is a twisted-pair or a coaxial application, surge protection selection is based on some basic questions. If the application is twisted pair, the four questions the user should ask are:

1. What is the application's nominal voltage?
2. What is the transmission speed of the data that are being passed?
3. What is the application's current rating?
4. How many pairs of these "twisted pairs" does the application include?

In selecting a surge protector, the nominal voltage of the twisted pair application must be known to assign a proper *clamping voltage*. According to Ohm's Law ($V = IR$), voltage is proportional to the current, keeping the series resistance constant. Once the voltage level reaches the surge protector's clamp voltage, the excess energy that may have damaged the dc communications equipment is diverted to a common earth/ground point.

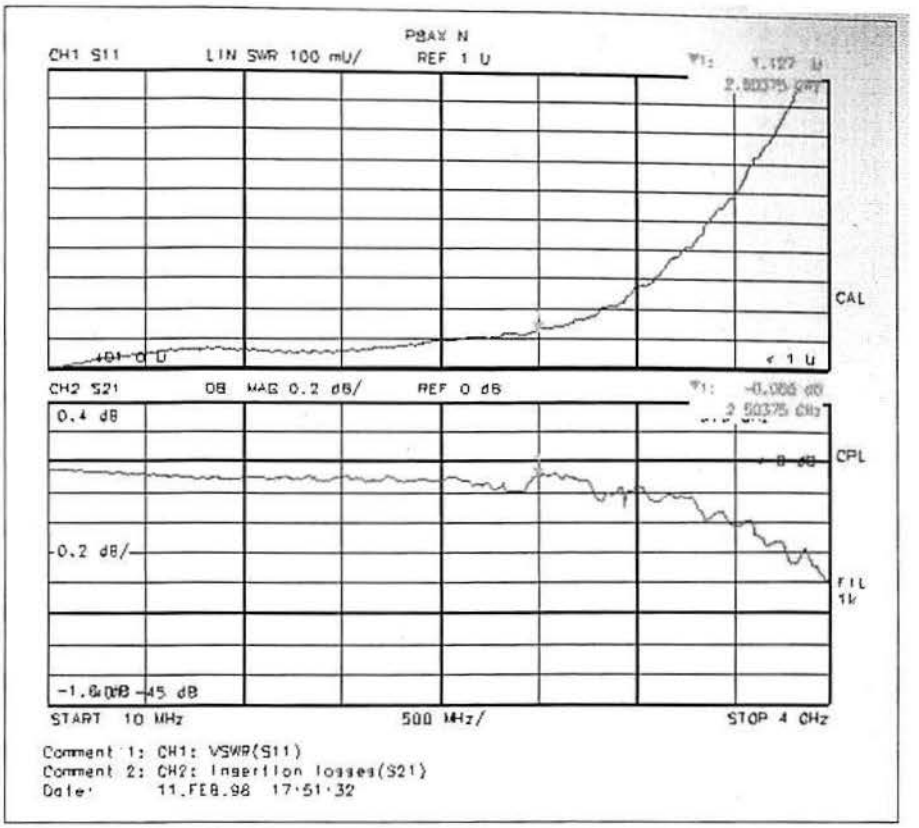

Figure 3: VSWR and insertion loss of a Citel, N-type coaxial surge protector.

As a rule, the clamping voltage of a surge protector should not exceed 1.4 times the application's nominal voltage. Clamping voltages for typical

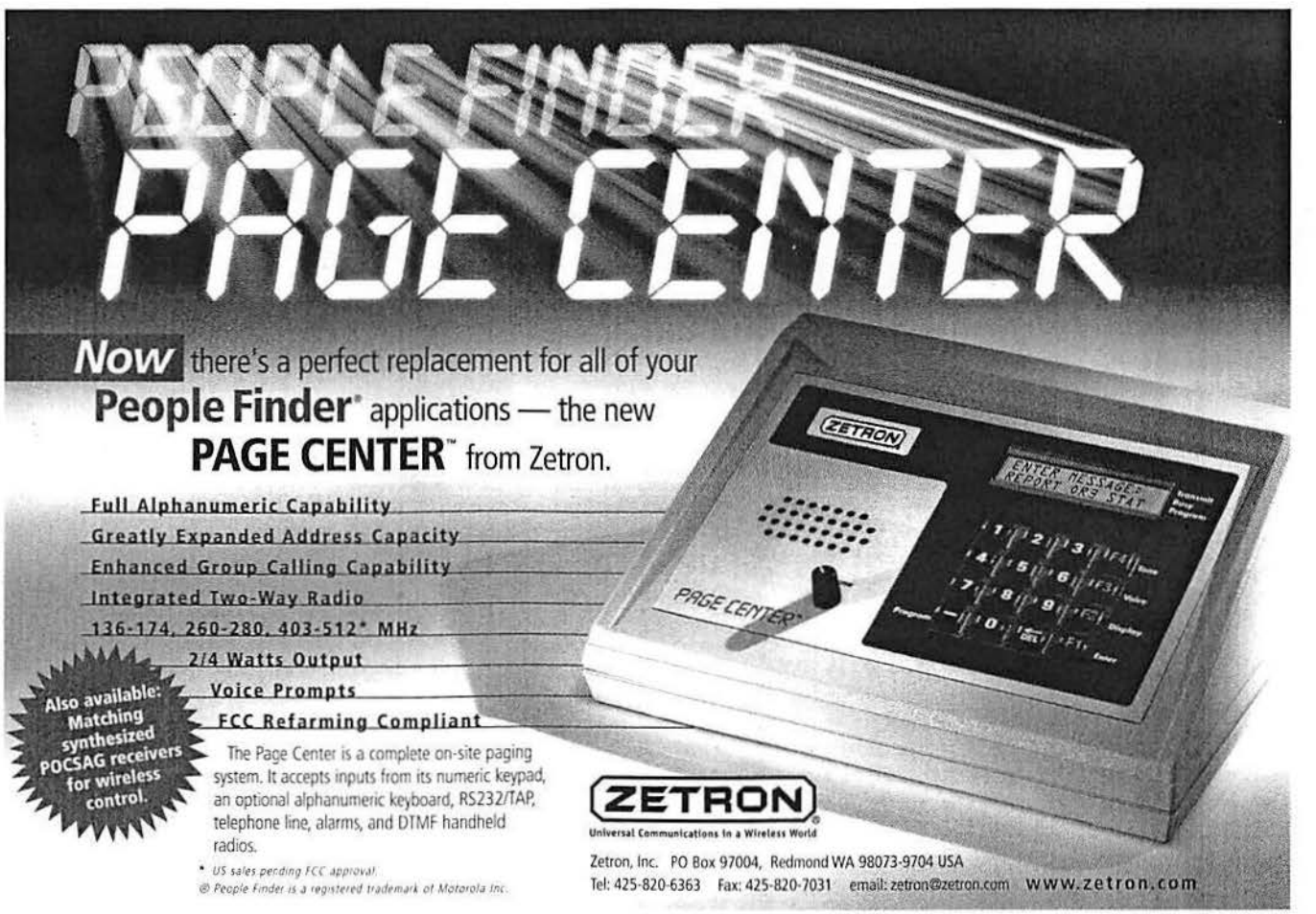
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Photo 1. Surge protector types (left to right): N-type with external ground screw; N-type bulkhead; BNC-type with external ground screw.

applications are shown in Table 1, above right.

In addition to knowing the application's nominal voltage, the transmission speed must be obtained. This information deals with the *capacitance* being placed on your twisted-pair line by the surge protector. This parameter is important for high-speed data rate applications such as Category 5, 10Base T, RS-485 and T1/E1. Capacitance can cause signal loss, or it can be the *source* of signal reflections if not properly used in a specific data line. To select a transient voltage surge supressor (TVSS) device with regards to capacitance and general protection against transient threats, it is recommended that the TVSS be first tested in the circuit under normal operating conditions.

NOTE: The transmission speed limit of standard data lines such as telephone lines, 4-20mA loops, and RS-232 is about 50kbps. Any application exceeding this limit should be considered a high-speed data (HSD) line, and a surge protector with a low capacitance should be chosen.

Identifying the *current rating* of the twisted-pair application is just as significant as the transmission speed and clamping voltage. TVSS devices for data lines such as RS-485, 4-20mA loops and telemetry equipment have

Table 1: Typical clamping voltages of common dataline applications

DATA LINE APPLICATION	CLAMPING VOLTAGE
RS-422	10V
Fire alarms	15V
RS-232	30V
Thermocouplers	30V
Leased lines	55V
Telephone lines with ringing voltage	190V

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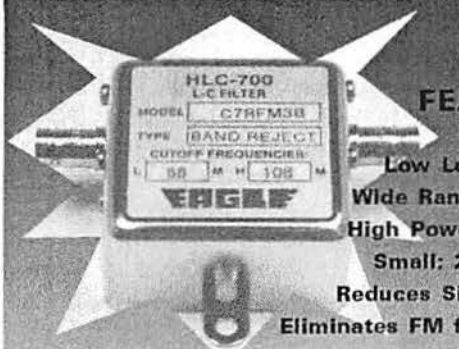

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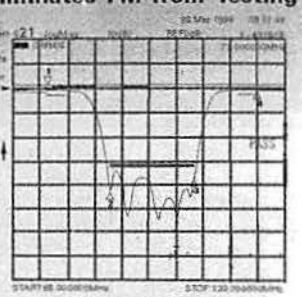

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current ratings of about 200mA. Applications that have higher current ratings (e.g., 500mA, 1A, and 2A) will cause premature failure to the surge protector with standard data line current ratings.

While determining the last three parameters, a simpler question must be kept in mind: How *many* of these twisted pairs need to be protected? Every wire connected to the equipment, even though it may not be in use, provides a path for harmful transients. In today's market, surge protector configurations range from one pair to 200- or 300-pair blocks.

Once all four parameters have been determined, the TVSS power-handling capability, also known as *peak pulse current* or *maximum discharge current,* should be investigated. These terms are defined as the maximum current that the surge protector can withstand for a given pulse duration. Pulse duration can be characterized as the length of time needed for the peak pulse current to reach a maximum value, plus the length of time needed for the peak pulse current to reach 50% of its peak value. Figure 2 on page 28 illustrates an 8/20μs waveform in which the power-handling capabilities of most surge protectors are commonly tested.

The waveform simulates "real-life" lightning-related surges. This is significant because the TVSS must be able to provide a low clamping voltage and be capable of diverting the lightning surge or industrial transient *away* from the dc communications equipment without short-circuiting.

Protecting coax

In a similar fashion, selecting appropriate coaxial surge protection boils down to four questions:

1. What is the application's frequency range?
2. What is the power rating?
3. What is the connector type of the application?
4. Is an in-line mounting style or a bulkhead mounting style preferred?

Coaxial surge protectors are composed of either gas-discharge tubes or quarter-wavelength stubs. In both cases, the frequency of the coaxial equipment must be known. For example, the operating frequencies of PCS and L-band applications are about 1.92GHz and 800MHz, respectively. Gas-discharge tube surge protectors generally have operating frequencies as high as 4GHz with low leakage currents and insertion losses. Figure 3 on page 29 illustrates an N-type coaxial surge protector with insertion losses so low (0.066dB at 2.5GHz, 0.2dB at 4GHz) that the protector is practically transparent on the coaxial cable.

In addition to the frequency of the coaxial application, the power rating must also be known to assign a proper clamping voltage. Standard gas-discharge tube protectors are available to protect power ratings as high as 50W, 400W and 1,000W (continuous). As with the twisted-pair protector, once the voltage level reaches the coaxial surge protector's clamp voltage, the excess energy that may have damaged the dc communications equipment is diverted to a common earth/ground point.

To connect the surge protector directly to the coaxial apparatus, a compatible connector type must be chosen. Common connector types are N-type, BNC, TNC, SMA and 7/16 DIN.

The installation type is also an issue. Typical mounting styles are available in in-line and bulkhead types. In-line protectors mount directly in-series with the coaxial cable, and grounding is done through an external ground screw that is attached to the body of the surge protector. The advantage to in-line protectors is that they are easy to install and they

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are suitable for retrofit applications. Bulkhead coaxial protectors are different only in the way they are grounded. Grounding is done through the chassis of the protector and the excess energy is discharged through the mounting panel. Bulkheads provide better electrical contacts for discharging excess energy from an electrical surge. Photo 1 on page 30 shows two types (with one modification) of coaxial surge protectors.

Placement of TVSS

Surge protectors should be installed at both ends of the dc communications line, whether they are for a twisted-pair or a coaxial application. Once transients have been diverted to earth/ground, they will continue to travel if there is a source of lower ground potential. Transients will travel to that source through the path of least resistance—probably a dataline. If only one end of the dc line is protected, a harmful transient can flow back into the dc communications line if the unprotected end is at a lower ground potential. With protection at both ends, it does not matter *where* the transient originates. It will always be shunted to earth/ground, regardless of the difference in ground potentials.

Proper grounding

A protection system with a poor ground is the same as having no protection at all. Proper earth/ground connections are often overlooked. Recommended grounds are the utility company ground, a ground rod, well casings, and cold-water pipes that are composed of *continuous* metal.

NOTE: Metal water pipes may at times be repaired and/or extended with PVC plastic piping. An interrupting section of PVC pipe nullifies the cold water pipe ground. Thorough investigation of a cold-water pipe is important because the PVC repairs or extensions may be hidden behind drywall, ceiling or flooring.

Grounds that are unacceptable include sprinkler pipes, PVC pipe, conduit, buried wire and *any ground that cannot be verified.*

> **Grounds that are unacceptable include sprinkler pipes, PVC pipe, conduit, buried wire and *any ground that cannot be verified.***

Bonding ensures the most effective ground. Bonding ties all of the grounds in the building together electrically, preventing differences in ground potentials. As a result, it is necessary to ensure that the ground used for the ac power is the same as the ground used for the dc communications surge protectors.

In connecting your surge protectors to a common ground point, all ground wires must be as short as possible. It is imperative that the ground wire not be coiled nor looped. Remember that transients will travel by the path of *least* resistance. The ground wire should be as straight as possible so that there is no obstruction to earth/ground. Conductivity is a function of wire *diameter,* as well as composition. The larger the diameter, the better the conductivity of the ground wire. Overall, grounding systems should have no more than 5Ω of earth/ground resistance.

Shielded applications

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total shield grounding at both ends, and those who are in favor of floating one of the ends of the shield.

The best shield performance is achieved when shield continuity is *not* broken and when shields are solidly grounded with a 360° termination to the chassis of the connected equipment at each end of the data/signal cable. However, the shield will provide a path for power frequency ground loops, which can degrade performance. Floating one end of the shield can eliminate these ground loops, but it can also lead to open-circuit voltages. These voltages can capacitively couple into the "protected" data conductors.

Standards and ratings

In some cases, the quality of surge protection is dictated by national or international standards such as ITU.K.22. This recommendation, in particular, seeks to recognize realistic facility transient stresses on telecommunication equipment connected to an internal ISDN T/S bus. The standard covers the following aspects of over-voltage and over-current conditions:

- ❑ surges due to lightning strikes on telecommunication lines or to the building housing the equipment.
- ❑ electrostatic discharges generated by users touching the equipment or adjacent plant.
- ❑ lightning transient surges on mains-voltage power supplies to the equipment.

Using the ITU.K.22 standard to protect facility equipment from transients will result in a protection scheme likely to provide immunity to naturally occurring transients within the facility. Achieving the desired protection will require the engineer to pay close attention to high-frequency events, such as suppressor response to high-frequency transients. The TVSS impulse discharge current rating should be adequate to handle the long-duration transients.

Other standards, such as UL497B, also provide a foundation of how communications line surge protectors should function under certain transient stress conditions. UL497B states that data communications and fire alarm circuit protectors consist of single- and multiple-pair air-gap arrestors, gas-tube arrestors, or solid-state arrestors, with or without fuses or other voltage-limiting devices. It also states that data communications and fire alarm circuit protectors are intended to protect equipment, wiring, and personnel against the effects of excessive potentials and currents caused by lightning in communication alarm-initiating or alarm-indicating loop circuits.

These industry standards, as well as ITU.K.22 and European markings such as CE, help determine if a surge protector will provide the level of protection required for sensitive communications equipment.

Take the proper steps

Data equipment is vulnerable to voltage surges and electrical transients. Users should be aware of the damage voltage surges, industrial transients and electrostatic discharges can inflict on expensive and delicate communication equipment. Without adequate protection, the door is left open to damaging electrical surges. Steps should be taken to identify the types of dc communication equipment that need protection and to match surge protection to them.

Companies such as Citel America have designed fast-acting, low-clamping, high-discharge surge protectors for all types of dc communications lines. TVSSs can divert to ground all damaging transient voltages while remaining transparent to the system they are are protecting. ■

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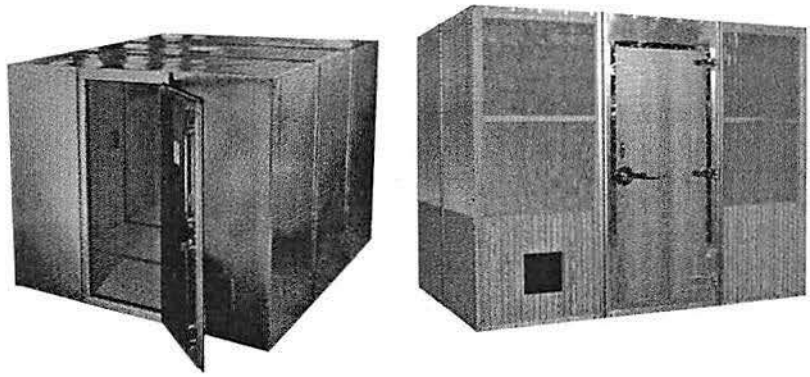

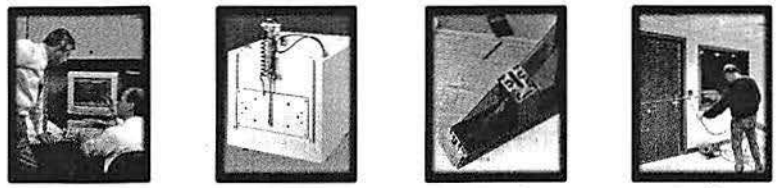

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